TITLE OF THE INVENTION

Cooling device including a biasing element

FIELD OF THE INVENTION

[0001] The present invention relates to cooling devices. More specifically, the present invention is concerned with a cooling device including a biasing element to removably secure the cooling device inside a stator of an electric machine.

BACKGROUND OF THE INVENTION

[0002] Many electric machines, such as electric motors and generators, among others, generate internal heat while operating. In many cases, this heat has to be continuously removed from the electric machine to prevent an undue increase in temperature that can make the device perform unsatisfactorily or even lead to device failure.

[0003] In these cases, a cooling device is connected to the electric machine to draw away excess heat. The cooling device typically includes means for dissipating the heat, such as, for example, fins, heat pipes or passageways suitable for allowing the circulation of a cooling fluid.

[0004] To draw heat from the electric machine, the cooling device has to be in physical contact with, and at a lower temperature than, the electric machine. Prior to operating, the cooling device and the motor are at a common temperature. However, because they differ in temperatures when operating, the electric machine typically undergoes a thermal expansion different from a thermal expansion of the cooling device. This difference in thermal expansion

may render the physical contact between the electric machine and the cooling device unsatisfactory.

[0005] To solve that problem, it is well known in the art to glue the cooling device to the electric machine with a heat-conducting adhesive. However, if the cooling device is inserted inside a cavity defined by the electric machine, the adhesive may not be strong enough to ensure that the physical contact is maintained. This may happen because the cooling device, as its temperature is lower, will typically expand less than the operating electric machine. Consequently, the cavity might become large enough to overwhelm the adhesive capacity of the adhesive.

[0006] Against this background, there exists a need in the industry to provide a novel cooling device for an electric machine.

OBJECTS OF THE INVENTION

[0007] An object of the present invention is therefore to provide an improved cooling device including a biasing element.

SUMMARY OF THE INVENTION

[0008] More specifically, in accordance with the present invention, there is provided a cooling device for an internal stator of an electric machine, the stator including a substantially cylindrical cavity defining a substantially cylindrical internal surface, the cooling device comprising:

a body defining an external substantially cylindrical contact surface; and

a biasing element connected to the body;

wherein the biasing element is so configured and sized as to bias the contact surface of the body against the internal surface of the rotor when the cooling device is positioned inside the cavity.

[0009] According to another aspect of the present invention, there is provided an electric machine comprising a cooling device for an internal stator of an electric machine, the stator including a substantially cylindrical cavity defining a substantially cylindrical internal surface, the cooling device including:

a body defining an external substantially cylindrical contact surface; and

a biasing element connected to the body;

wherein the biasing element is so configured and sized as to bias the contact surface of the body against the internal surface of the rotor when the cooling device is positioned inside the cavity.

[0010] According to another aspect of the present invention, there is provided a cooling device for an internal stator of an electric machine, the stator including a substantially cylindrical cavity defining a substantially cylindrical internal surface, the cooling device comprising :

a body defining an external substantially cylindrical contact surface; and

biasing means connected to the body, the biasing means being so configured and sized as to bias the contact surface of the body against the internal surface of the rotor when the cooling device is positioned inside the cavity.

[0011] According to yet another aspect of the present invention, there is provided a cooling device for an internal stator of an electric machine, the stator including a cavity defining an internal surface, the cooling device comprising:

a body defining an external contact surface; and

a biasing element connected to the body;

wherein the biasing element and the body are so configured and sized as to bias the contact surface of the body against the internal surface of the rotor when the cooling device is positioned inside the cavity.

[0012] Other objects, advantages and features of the present invention will become more apparent upon reading of the following non-restrictive description of preferred embodiments thereof, given by way of example only with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] In the appended drawings:

[0014] Figure 1 is a perspective view of an embodiment of a cooling device according to an embodiment of the present invention positioned in a cavity of a stator of an electric machine;

[0015] Figure 2 is a perspective view of the cooling device of Figure 1;

[0016] Figure 3 is a perspective exploded view of the cooling device of Figure 1;

[0017] Figure 4 is a top plan view of the cooling device of Figure 1;

[0018] Figure 5 is a side cross-sectional view taken along line 5-5 of Figure 4;

[0019] Figure 6 is a perspective view illustrating an insertion of a cooling device according to a second embodiment of the present invention into a cavity of a stator of an electric machine;

[0020] Figure 7 is a top plan view of a third embodiment of a cooling device for a stator of an electric machine;

[0021] Figure 8 is a top plan view of a fourth embodiment of a cooling device for a stator of an electric machine;

[0022] Figure 9 is a top plan view of a fifth embodiment of a cooling device for a stator of an electric machine;

[0023] Figure 10 is a top plan view of yet a sisth embodiment of a cooling device for a stator of an electric machine;

[0024] Figure 11 is a top plan view of a seventh embodiment of a cooling device for a stator of an electric machine; and

[0025] Figure 12 is a top plan view of an eight embodiment of a cooling device for a stator of an electric machine.

DETAILED DESCRIPTION

[0026] In a nutshell, embodiments of the present invention provide an efficient means for mounting a cooling device inside a stator of an electric machine. The electric machine may be of the internal stator – external rotor type. The general principle is to provide a biasing element, integral or external

with the cooling body that will ensure an adequate contact between the cooling body and the internal surface of the stator.

[0027] Figure 1 shows a cooling device 20 mounted in an internal stator 22 of an electric machine. As shown on Figure 6, the stator 22 includes a cylindrical cavity 24 having a cylindrical internal surface 26.

[0028] As can be better seen from Figure 2, the cooling device 20 includes a body 28 defining an external cylindrical contact surface 30, a top surface 32 and a bottom surface 34. A top cover 36 and a bottom cover 38 are removably mounted to the top and bottom surfaces, respectively. The covers 36 and 38 are used to close a cooling passageway provided in the body 28.

[0029] More specifically, the cooling passageway 40 includes an inlet 42 for accepting the cooling fluid and an outlet 44 for releasing the cooling fluid. The cooling fluid takes heat away from the body 28, thereby allowing the body 28 to maintain a temperature lower than a temperature of the stator 22. Apparatuses and methods for causing a circulation of a cooling fluid in the cooling passageway and means for disposing of the heat taken away by the cooling fluid are well known in the art and will therefore not be discussed in further details.

[0030] The cooling passageway includes a plurality of indentations 46 in each of the top and bottom surfaces 32 and 34 and a plurality of cooling conduits 48 extending generally axially through the body 28. The cooling conduits 48 are in a fluid communication relationship with the indentations 46. Each of the top and bottom covers 36 and 38 is generally shaped as the top and bottom surfaces 32 and 34 of the body 28 and close the indentations 46 to produce, in conjunction with the cooling conduits 48, a closed passageway for accepting the cooling fluid. Methods and apparatuses for connecting the top

and bottom covers 36 and 38 to the body 28 are believed well known in the art and will therefore not be detailed herein.

[0031] Returning to Figure 2, the cooling device 20 also includes a biasing assembly 50 that is so configured and sized as to bias the contact surface 30 of the body 28 against the internal surface 26 of the stator 22 when the cooling device 20 is positioned inside the cavity 24.

[0032] The biasing assembly 50 includes first and second wedging devices 52 and 54 maintained together by fastening assemblies 56. The biasing assembly 50 is to be mounted to the body 28 via opposed surfaces 58 and 60 of the body 28 as will be described hereinbelow. These opposed surfaces are defined by the generally C-shape of the body 28.

[0033] In the specific example illustrated in Figures 1 to 5, the first and second opposed surfaces 58 and 60 are convex. More specifically, each of the first and second surfaces 58 and 60 present a substantially trapezoidal cross-section, as can be better seen from Figure 4. In addition, the first and second wedging devices 52 and 54 each have a trapezoidal cross-section and have a longitudinal dimension substantially equal to a longitudinal dimension of the body 28.

[0034] The number of fastening assemblies 56 is not critical to the invention. Each fastening assembly 56 includes a deformable and biasing portion that transmits a reaction force to the first and second wedging devices 52 and 54 as will be described hereinbelow.

[0035] As shown more clearly on Figure 5, each of the first and second wedging devices 52 and 54 includes fastening apertures 62 to accept a

part of the fastening assembly. Furthermore, the wedging device 52 includes shoulder portions 64 to accept the head of a fastener.

[0036] Each fastening assembly 56 includes a bolt 66 inserted through the shoulder portion 64 and the matched fastening apertures 62 of the first and second wedging devices 52 and 54. A deformable portion in the form of a disc springs 68 is inserted onto each bolt 66 between the second wedging device 54 and a respective first nut 70. The disc springs 630 include, for example, one or more Belleville spring washers mounted in series. However, many other types of disc springs could be used. In addition, a second nut 72 is threaded onto each bolt 66 to positively lock the nuts onto the bolt.

[0037] To mount the cooling device 20 in the stator 22, the cooling device 20 without the biasing assembly 50, or with the biasing assembly 50 in an non-biasing position, is inserted inside the cavity 24 of the stator 22. The nuts 70 of the fastening assemblies 56 are then tightened until a good contact exists between the external surface 30 of the body 28 and the internal surface 26 of the stator 22. Indeed, by tightening the fastener assemblies 56, the wedging devices 52 and 54 are pulled towards one another. The corresponding trapezoidal shape of the wedging devices 51 and 54 and of the first and second opposed surfaces 58 and 60 force the opposed surfaces 58 and 60 apart from one another, thereby forcing the external surface 30 onto the internal surface 26.

[0038] Via this good contact between the external surface 30 and the internal surface 26, the cooling device 20 draws heat away from the stator 22. Specifically, whenever a temperature of the electric machine is higher than a temperature of the body 28, heat flows away from the stator 22 through the internal surface 26 of the cavity 24 to enter the body 28 through the contact surface 30.

[0039] To maintain the position between the cooling device 20 and the stator 22, the stator 22 optionally includes a key 74 extending from the internal surface 26, and the body 28 includes a keyway 76 in the contact surface 30. The keyway 76 is configured and sized to engage the key 74, thereby preventing a rotational motion of the cooling device 20 inside the stator 22.

[0040] The reader skilled in the art will readily appreciate that the cylindrical shape of the cavity 26 and of the body 28, which produce a circular cross-section, is not essential. For example, the body and the cavity could assume various cross-sections, such as an ovoid, an ellipse or a polygon, among others (not illustrated in the drawings). In fact, the body and the cavity can assume any suitable shape as long as they allow the biasing assembly to bias the contact surface of the body against the internal surface of the stator when the cooling device is positioned inside the cavity.

[0041] Turning now to Figure 6 of the appended drawings, an alternate embodiment of a cooling device 100 will briefly be described. For concision purposes, only the differences between the cooling device 20 and the cooling device 100 will be described hereinbelow.

[0042] The main difference concerns cooling passageway that includes an indentation 102 in the contact surface 104 of the body 106. The indentation is configured to receive a cooling tube 108 having an inlet 110 and an outlet 112. The cooling fluid may circulate in the cooling tube 108. In addition, the indentation 102 assumes a generally horizontally oriented serpentine geometric configuration and is in direct contact with the internal surface 26 of the stator 22. However, the reader skilled in the art will readily appreciate that many other suitable geometric configuration are possible without detracting from the claimed invention.

[0043] It is to be noted that the biasing assembly 50 is identical to the biasing assembly of Figures 1 to 5.

[0044] In a second example of implementation of the present invention, the biasing element includes an expansion spring positioned between and connected to the first and second opposed surfaces. As shown on Figures 7 to 10, the expansion spring can take many forms.

[0045] In the embodiment shown in top view on Figure 7, a cooling device 200 has first and second opposed surfaces 202 and 204 each including a respective generally T-shaped protrusion 206 and 208. The generally T-shaped protrusions are so configured and shaped as to retain an expansion spring in the form of two generally cylindrical leaf-springs 210 and 212 by each enclosing a side of one of the generally cylindrical leaf-springs. Each generally cylindrical leaf-spring 210 and 212 extends from the top surface of the body 214 to the bottom surface of the body.

[0046] The body 214 also includes apertures 216 and 218 provided near each of the opposed faces 202 and 204. The apertures 216 and 218 are used to compress the body 214 (see dashed lines) to allow the insertion of the body inside the stator (not shown). More specifically, pins (not shown) are inserted in the apertures 216 and 218 and are moved towards one another (see arrows 220) to compress the springs 210 and 212 to thereby overcome the biasing action of the springs and allow the deformation of the body for its insertion in the stator. When the body is inserted in the stator, the pressure on the pins may be relaxed that the biasing action of the springs force the contact between the contact surfaces.

[0047] Turning now to Figure 8, a cooling device 300 includes generally flat opposed surfaces 302 and 304 and two leaf-springs 306 and 308

are maintained in notches 310 extending longitudinally on the opposed surfaces 302 and 304. The generally cylindrical leaf-springs 302 and 304 are similar in shape and function to the leaf-springs 210 and 202 shown on Figure 7.

[0048] Again, apertures 216 and 218 are provided to compress the leaf-springs 302 and 304.

[0049] Of course, any number of leaf-springs could be used without detracting from the present invention.

[0050] In a further alternative embodiment shown on Figure 9, a cooling device 400 includes one leaf-spring 402 that is retained between the two opposed surfaces 404 and 406 by two notches 408 extending longitudinally on the second opposed surface 406. While not an essential requirement, the first opposed surface 404 can be flat, as illustrated. Once again, the leaf-spring 402 is similar in shape and function to the leaf-springs 202 and 212.

[0051] In yet a further alternative embodiment shown on Figure 10, a cooling device 500 includes one or more coil springs 502 are inserted between the first and second opposed surfaces 504 and 506 within two shoulders 508. Each shoulder 508 is located on one of the first and second opposed surfaces 504 and 506 and receives one end of one of the coil springs 502.

[0052] In a further variant illustrated on Figure 11, a cooling device 600 includes a body 602 includes an integral spring 604.

[0053] The spring 604 is defined by a first longitudinal cut tangential to the external surface 606, the first cut defining a first channel 608 within the

body 602. The spring 604 further includes a second longitudinal cut tangential to the internal surface 610, the second cut defining a second channel 612 within the body 602. The first and second channels 608 and 612 allow an elastic deformation of the spring 604 as can be seen in dashed lines in Figure 11. It is believed that one skilled in the art will be in a position to determine the dimension and number of the cuts that should be made to the body 602 to enable a sufficient elastic deformation of the body 602 for its insertion into the stator.

[0054] Of course, one skilled in the art will understand that more than one integral spring such as 604 could be used.

[0055] A cooling device 700 according to an eight embodiment of the present invention is illustrated in Figure 12. The cooling device 700 includes two identical body elements 702 and 704 together defining a generally circular cross-section body. The interconnection between the body elements 702 and 704 is identical to the interconnection between the facing ends 202 and 204 of the cooling device 200 of Figure 7 and will therefore not be described further for concision purposes.

[0056] It is to be noted that the biasing means used to force the external surface of the body elements 702 and 704 towards the internal contact surface of the stator could be different, for example as illustrated in the other embodiments herein.

[0057] Having two body elements 702 and 704 may be interesting in some situations since it is not required to exert a compressive force to insert the body elements into the stator since the elements may be inserted one at a time and the biasing elements can be mounted thereto once the elements are in the stator.

[0058] In a specific example of implementation, the components of the cooling device are metallic. While not essential to the invention, the use of metals provide suitable strength and heat conduction capability to the cooling device. For example, aluminum has been used successfully. Alternatively, some of the elements, such as the covers 36 and 38 could be made of other materials, such as composite material, if weight is an issue for a particular application.

[0059] In the embodiments and variants presented herein above, and non-limitatively, the cooling device is inserted into the cavity as follows. First, an external compressive force is exerted on the body. The external force deforms the body and is transmitted to a spring included in the cooling device, thereby causing the spring to deform. In the drawings, the deformation of the body under the external force is illustrated by dashed contours slightly offset from the solid lines representing the body. Further to an insertion of the cooling device into the cavity, the external force is removed. Then, the spring causes an expansion force to be applied on the body, thereby biasing the contact surface of the body against the internal surface of the stator.

[0060] It is to be noted that while the embodiments of the cooling devices shown herein all use tubes carrying a cooling fluid to remove excess heat from the body of the cooling device, other excess heat removal devices such as fins and/or heat pipes could be used. These elements are believed well known in the art and will not be discussed in details herein.

[0061] Although the present invention has been described hereinabove by way of preferred embodiments thereof, it can be modified, without departing from the spirit and nature of the subject invention as defined in the appended claims.